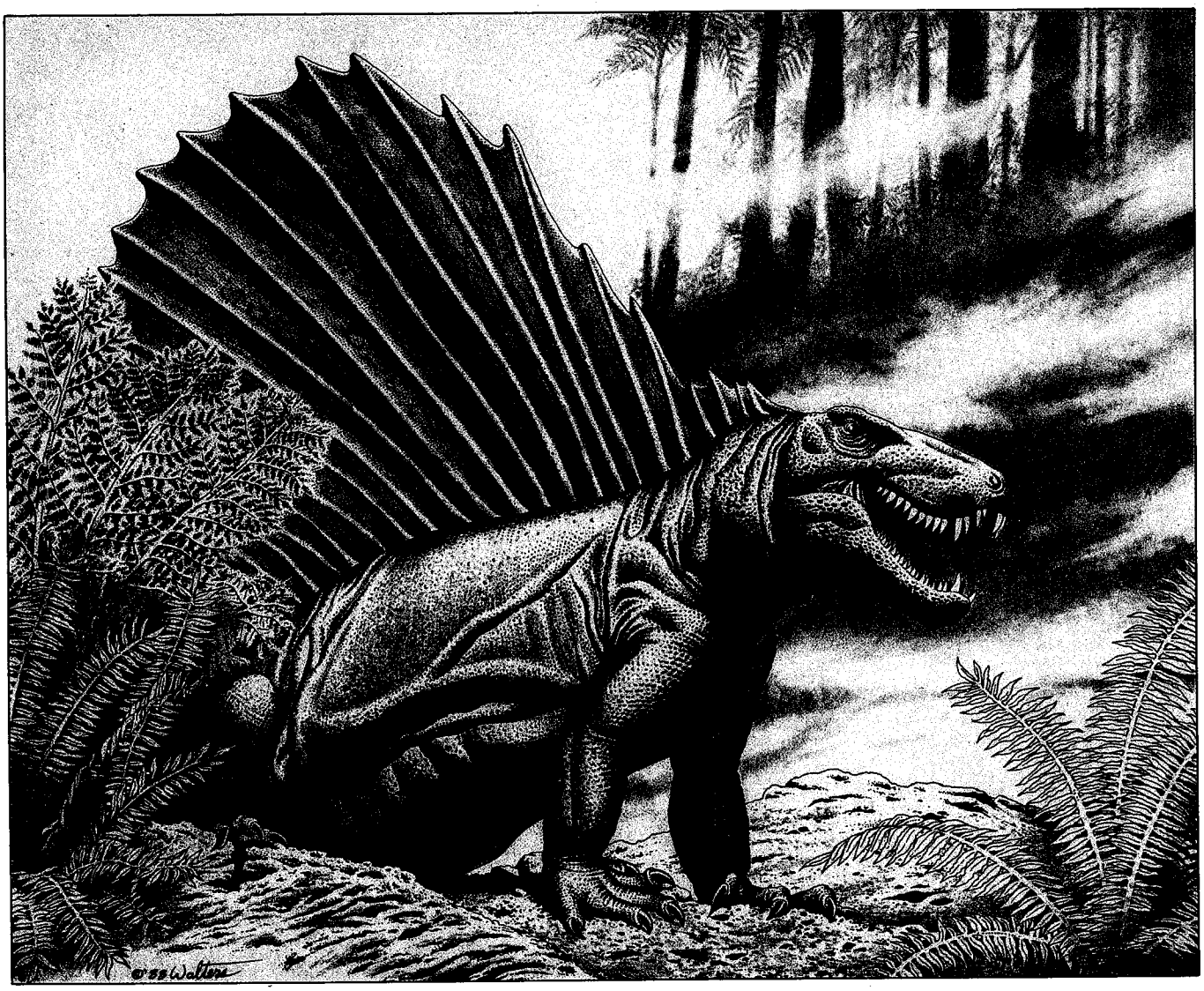
THE MOSASAUR



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The Mosasaur

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The Upper Cretaceous (Campanian, Black Creek Formation) Fossil Fish Fauna of Phoebus Landing, Bladen County, North Carolina

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Abstract

Phoebus Landing, Bladen County, North Carolina, has recently produced a spectacular array of Late Cretaceous (Campanian) vertebrate fossils from the Black Creek Formation, including a superb fish fauna. This study represents the most complete survey to date of the Black Creek fish of North Carolina. Twenty-one fish taxa have been recognized. The chondrichthyan taxa represented are: *Hybodus montanensis*, *Hybodus* sp., *Odontaspis samhammeri*, *Synodontaspis holmdelensis*, *Squalicorax kaupi*, *S.pristodontus*, *Scapanorhynchus texanus*, *Squatina hassaei*, *Ischyrhiza mira*, *Rhombodus levis*, *Brachyrhizodus wichataensis*, and *Ischyodus* cf. *I. bifurcatus*. The osteichthyan constituents include: Lepisosteidae indet., *Anomaeodus phaseolus*, *Xiphactinus audax*, *Saurodon* sp., *Albula* sp., *Paralbula casei*, *Enchodus* cf. *E. petrosus*, *Cylindracanthus ornatus*, and *Stephanodus* sp. This Campanian fish assemblage is quite distinct from the Late Maastrichtian faunas of North Carolina and elsewhere, resembling more in content the Campanian faunas of New Jersey, Delaware, Maryland, Georgia, Texas, Kansas, Montana, and Wyoming.

Introduction

As early as 1858, Ebenezer Emmons reported Cretaceous vertebrate fossils from along the Cape Fear River in southeastern North Carolina. Since that time, these fossils, especially at Phoebus Landing, Bladen County, have received sporadic but diligent attention. Study of these fossils has been sporadic due to the inaccessibility of the locality. As recently as 1950, Horace G. Richards reported the locality as being "completely covered with silt and debris and impossible to find." Since then, the site has become accessible and is once again producing a spectacular array of Black Creek fossil vertebrates. A diverse fish fauna including chondrichthyans and osteichthyans is present, as well as mosasaurs, turtles, crocodiles, and dinosaurs.

The fossil vertebrates, including the fish, of the Black Creek Formation of North Carolina have been described by numerous authors, including Leidy (1856a,b), Emmons (1858), Cope (1871, 1875), Stephenson (1912, 1923), Richards (1950), Miller (1966, 1967, 1968), and Baird & Horner (1979). Unfortunately, most authors only repeated the taxonomic lists of previous writers. Baird & Horner (1979, p. 24) published the most recent and complete revision of the list of vertebrate taxa present at Phoebus Landing. Gerard R. Case, prepared the list of fish taxa for Baird & Horner (Table 1). Most significantly, Case revised the identifications of fish taxa by previous authors.

The locality at Phoebus Landing has always been cited as the foremost producer of fish in the Black Creek Formation of North Carolina. The present accessibility of the site allows a more complete and definitive fish study. This study will attempt to bring the knowledge of the Cretaceous (Campanian) fish fauna of North Carolina on a par with that of faunas from New Jersey, Delaware, Maryland, Georgia, Alabama, Texas, Montana, and Wyoming.

Location

Phoebus Landing is located along the southern bank of the Cape Fear River approximately one-quarter mile downstream of mile 68, just east-southeast of Elizabethtown,

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Table 1.

List of fossil fish remains reported to occur at Phoebus Landing by Baird & Horner (1979, p. 24).

Class Chondrichthyes
- *Asteracanthus* sp.
- *Scapanorhynchus texanus* (Roemer)
- *Squalicorax pristodontus* (Agassiz)
- *Ischyrhiza mira* Leidy
- *Brachyrhizodus wichitaensis* Romer

Class Osteichthyes
- *Paralbula casei* Estes
- *Pycnodus phaseolus* Hay

Bladen County, North Carolina. The locality is most easily accessible from the waterway, as the overland route traverses private property filled with dense vegetation and numerous swamps.

Geology

Erosion by the Cape Fear River has exposed deposits of the Late Cretaceous (Campanian) Black Creek Formation at Phoebus Landing. The Black Creek Formation of North Carolina correlates with the Matawan Group of New Jersey, Delaware, and Maryland, and with the Selma Chalk of Alabama (Richards, 1950, p. 9). Stephenson (1923, p. 10) considers the deposits at Phoebus Landing to be from the uppermost Black Creek Formation, within the *Exogyra ponderosa* zone. According to Heron & Wheeler (1964, p. 21): "The Black Creek formation consists of poorly indurated, laminated or thin-bedded clayey silts and silty clays, dark clays, and loose, coarse light gray, well sorted sand, as well as thick lenses of this sand. These sands, silts, and clays contain substantial quantities of glauconite, lignite, shell material, iron sulphide, and some amounts of phosphate, amber, marine microfossils." Several distinct types of stratification can be recognized in the Black Creek Formation, including fluvial deposits, fluviomarine bedding, lagoonal strata, and littoral lenses (Baird & Horner, 1979, p. 5, from an unpublished dissertation by Donald J. Swift, 1954).

The Black Creek exposure at Phoebus Landing consists of a gently sloping, unconsolidated lens of channel-fill composed primarily of clayey silts, clay concretions, coarse sands, and pebbles. The bone-bearing lens is over- and underlain by clayey beds. These clayey layers have produced sparse vertebrate remains but are essentially barren of fossils except for isolated layers of lignite and other plant matter. Although the bone-bearing lens contains bones probably reworked from the underlying Black Creek clays, the sand lens itself does not appear to have been produced by reworking. According to Miller (1967, p. 220), the "channel sands seem to be abundant within the Black Creek Formation. Therefore, it is unlikely that the bone bed formed as a portion of the Black Creek formation and was not a later erosional-depositional 'intrusive'."

Paleoecology

In assessing the Black Creek Formation around Elizabethtown, Brett & Wheeler (1961, p. 102) concluded, "The stratigraphic situation along the Cape Fear River indicates an onlap condition during Upper Cretaceous times within an encroachment of the ocean onto a gently sloping coastal plain . . . ." According to Miller (1967, p.221), the lithology and faunal content of the bone-bearing lens at Phoebus Landing suggests a "nearshore, freshwater and tidal brackish-water stream that flowed across the marine shale after a slight regression of the sea." Terrestrial vertebrates (such as dinosaurs) could have been deposited by stream flow, and marine forms by current and tidal action. Baird & Horner (1979, p. 6) concur that the ecologically diverse nature of the vertebrate fauna of the Black Creek Formation at this location suggests these varied depositional circumstances. More recently, Gallagher et al. (1986) established the similarities between the depositional environment for Phoebus Landing and that of the Ellisdale, New Jersey, locality. They describe the paleoecology as follows (p. 24):

> "Fluvial systems transport taphonomically mature terrestrial biota into river mouths, embayments, and estuaries, where bones and plant material are trapped. Typically marine animals come into estuaries to feed and breed; environmental stresses cause mortality of these animals. Additionally, dead associated with reproduction (e.g., sea turtles) plays a part. Episodic redeposition and mixing is accomplished by major storm events such as seasonal hurricanes, nor'easters, or monsoons. In the case of the Upper Cretaceous deposits, these storms may have been generated by a Tethyan climatic regime . . . . Storm surges over barrier beaches and increased flow through tidal channels are specific mixing mechanisms. Seasonal storms are 'killing seasons' when many different populations suffer higher mortality rates. Transgressive phases are optimum times for mixed-assemblage deposition. Mixed scrap faunas became possible in the Mesozoic and Cenozoic when large terrestrial vertebrates became relatively common, and when passive margins were widespread due to the break-up of Pangaea."

Paleontology

Invertebrates

Invertebrate fossils are very uncommon at Phoebus Landing. Invertebrates exhibiting original calcium carbonate shell material are extremely rare. The absence of shelled invertebrate remains is most likely due to the destructive effects of ground water in the sandy layer. Most of the invertebrates recovered at Phoebus Landing consist of steinkerns of molluscs (Gastropoda and Pelecypoda). Sohl & Christopher (1983, pp. 7-10) report approximately 177 species of invertebrates and 31 pollen species from the Black Creek Formation in a zone along the Cape Fear River just south of Phoebus Landing.

Paleobotany

The Black Creek clays above and below the bone-bearing layer contain lignite and other plant material, including mats of leaves. Stephenson (1912, p. 125) reports nine species of plant fossils from the Black Creek Formation at Sykes Landing (mile 74 of the Cape Fear River) and Big Bend (mile 73).

Vertebrates

Due to the depositional environment, the bone-bearing lens at Phoebus Landing preserves a heterogeneous mixture of terrestrial, lagoonal, and marine vertebrates. Terrestrial and amphibious dinosaurs, crocodiles, and turtles, along with marine reptiles and fish, are recovered from the same deposit. Most larger specimens are damaged or fragmentary due to the nature of deposition, although many specimens exhibit very fine details in preservation.

The diverse fish fauna contains both cartilaginous fish (chondrichthyans) and bony fish (osteichthyans) (Table 2). The fish taxa are described in the systematics section of this paper. An equally impressive reptilian assemblage is present (Table 3). I am indebted to William B. Gallagher of the New Jersey State Museum for reviewing and revising the reptilian taxonomic list.

Repositories for Specimens

ANSP	Academy of Natural Sciences of Philadelphia
NJSM	New Jersey State Museum, Trenton
USNM	National Museum of Natural History, Smithsonian Institution

Additional specimens are deposited in the collections of the Sternberg Museum at Ft. Hays, Kansas, and in the author's private collection.

Systematic Paleontology

Complete synonymies for the chondrichthyan taxa cited can be located in Lauginiger & Hartstein (1983) and Cappetta & Case (1975). Some osteichthyan synonymies are listed in Fowler (1911). Systematic classification was adapted from a combination of those presented by Romer (1966), Cappetta (1987), and Carroll (1988).

Distributional data was derived from the following sources: for New Jersey, Cappetta & Case (1975), Case (1978b), Estes (1969), Fowler (1911), Gallagher et al. (1986), Lauginiger (1986), Parris et al. (1987); for Delaware, Lauginiger & Hartstein (1983); for Maryland, Hartstein & Decina (1986); for North Carolina, Case (1979a); for Georgia, Case & Schwimmer (1988), Schwimmer (1986); and for western states, Bardack (1965), Case (1978a, 1979b), Cope (1874), Goody (1976), Leidy (1856a, 1870, 1873), Stewart (1900).

Class Chondrichthyes
Subclass Elasmobranchii
Superorder Euselachii
Order Ctenacanthiformes
Family Hybodontidae
Genus *Hybodus* Agassiz, 1837
Hybodus montanensis Case, 1978
(Figures 1A-B, 2A-C)

Hybodus montanensis Case, 1978a, pp. 180-183, text-figs. 2-4; pl. 2, figs. 1a-c.

Material: NJSM 14174, 14611 (teeth).

Description:

Both teeth and dorsal fin spines of this shark have been recovered at Phoebus Landing, although no cephalic clasper hooks have been recognized. The teeth of *Hybodus montanensis* range in size from 0.5 cm to 2.0 cm in height. Most teeth are rootless, although several possess root structures. The main blade of the tooth is lingually curved with relatively thick longitudinal striations on the lingual face. Deep plications occupy

Table 2.

Faunal list of fish fossils which occur at Phoebus Landing, North Carolina.

	Common Name
Class Chondrichthyes	
Hybodus montanensis Case	hybodont shark
Hybodus sp.	do.
Odontaspis samhammeri Cappetta & Case	sand shark
Synodontaspis holmdelensis (Cappetta & Case)	do.
Squalicorax kaupi (Agassiz)	extinct crow shark
S. pristodontus (Agassiz)	do.
Scapanorhynchus texanus (Roemer)	goblin shark
Squatina hassei Leriche	angel shark
Ischyrhiza mira Leidy	ganopristine shark
Rhombodus levis Cappetta & Case	ancestral ray
Brachyrhizodus wichitaensis Romer	cow-nosed ray
Ischyodus cf. *I. bifurcatus* Case	ratfish
Class Osteichthyes	
Lepisosteidae indet.	garfish
Anomoeodus phaseolus (Hay)	extinct pycnodontid fish
Xiphactinus audax Leidy	primitive tarpon
Saurodon sp.	osteoglossomorph fish
Albula sp.	bonefish
Paralbula casei Estes	primitive ladyfish
Enchodus cf. *E. petrosus* Cope	primitive salmon
Cylindracanthus ornatus Leidy	[affinities unknown]
Stephanodus sp.	extinct triggerfish

Table 3.

Reptilian taxa (Class Reptilia) from Phoebus Landing, North Carolina.

Order Chelonia (turtles)
- *Adocus* sp.
- *Bothremys barberi* (Schmidt)
- *Trionyx halophilus* Cope
- *Taphrosphys dares* Hay

Order Squamata, Family Mosasauridae (mosasaurs)
- *Tylosaurus* sp.
- *Prognathodon* sp.
- *Halosaurus* sp.
- *Platecarpus* sp.

Order Crocodilia (crocodiles and alligators)
- *Deinosuchus* (*Phobosuchus*) *rugosus* (Emmons)
- cf. *Thoracosaurus neocessariensis* Dekay
- *Brachychampsa* sp.
- *Leidyosuchus* cf. *L. fomidabilis* Erickson

Order Saurischia, Suborder Theropoda
- Suborder Theropoda (theropod dinosaurs)
  - *Dryptosaurus* sp.
  - *Ornithomimus* sp.
- Suborder Sauropodomorpha (sauropod dinosaurs)
  - *Hypsibema crassicauda* Cope (may possibly be a hadrosaur; W. B. Gallagher, personal communication)

Order Ornithischia, Suborder Ornithopoda (ornithopod dinosaurs)
- Hadrosaurinae indet.

the basal one-third of the blade. Teeth from this species rarely possess lateral cusplet, although very small residual cusplets may be present on lateral teeth (Figures 1a-b).

Also recovered are the dorsal fin spines of this hybodont shark. The average length of a relatively complete spine is 14.0 cm, although most spines recovered are incomplete or fractured into multiple sections. The fin spines taper longitudinally from a broad base and also taper from a relatively widely convex posterior edge to a thin anterior edge. The convex posterior surface is lined with medially alternating "tooth-like" projections. These spines, assigned to *Hybodus montanensis* by Case (1978a, p. 181, text-fig. 3a), possess longitudinal striae on the lateral faces and are thicker in cross-section than the spines attributed to *Hybodus* sp. (Figures 2A-C).

Cephalic clasper hooks of hybodont sharks are present at this locality, although no specimens resembling those described by Case (1978a, p. 182) as belonging to *Hybodus montanensis* have so far been recovered. According to Case, "the basal platform of the appendage is . . . ovoid in its overall silhouette, with a . . . robust hook extension arching dorsally from the anterior edge of the platform." These cephalic clasper hooks are pictured by Case (1978a, figs. 4A, 1-3) as *Hybodus* sp. 1.

Discussion:

Hybodont shark material is relatively common at this locality, with the indeterminate teeth being the most frequent fossil form recovered. Since most *Hybodus* teeth recovered are fragmentary, specimens which can definitely be assigned to this species are very rare. Spines of this species are far less common than those which are assigned to *Hybodus* sp. No cephalic clasper hooks which can definitely be assigned to this species have been recovered, but can be expected. This species was first described from the Judith River Formation (Campanian) of Montana and illustrated incorrectly with lateral cusplets; the specimen actually illustrated and partially described is *H. wyomingensis* (Case, 1987, p. 7).

Hybodus sp.
(Figures 1C, 2D-E, 3A-B)

Material: USNM 421725 (teeth); NJSM 14618 (tooth), 14612 (cephalic clasper hook).

Description:

These indeterminate *Hybodus* fossils apeak to be the same as those described by Cappetta & Case (1975, pp. 4-6) and Case (1978a, pp. 181-182; 1979, p. 79) as *Hybodus* sp. 1. The teeth assigned to *Hybodus* sp. differ from those of *H. montanensis* by the presence of distinct lateral cusplets and the extent of the plications on the labial aspect of the blade. The lateral cusplets are approximately one-third the height of the main blade of the tooth. According to Case (1979a, p. 79), the plications on the teeth of this shark rise from the apron of the blade to approximately one-fifth the total height of the blade. The other characteristics of these teeth very closely parallel those of *H. montanensis.*

The dorsal fin spines exhibit the same overall appearance as the spines of *H. montanensis* except that the lateral faces are tuberculated rather than striated, and the spines are more laterally compressed in cross-section (Figures 2D-E). Cephalic clasper hooks which can be assigned to *Hybodus* sp. are also recovered. These hooks are dense cartilage structures with three finger-like projections on the posterior end and one broad extension on the anterior end. The anterior extension often has an enameloid tip, and the entire hook is generally curved if viewed laterally (Figure 3).

Discussion:

This author believes that the presence of lateral cusplets serves as the most significant characteristic for distinguishing between teeth of the two species of hybodont sharks at this locality. The specimens from Phoebus Landing exhibit labial plications ranging from barely present to over one-third of the blade length. A specific determination based solely on this feature would not be appropriate. It is believed that most teeth belong to *Hybodus* sp., based on the fact that its dorsal spines are far more common at this locality.

Hybodont shark material, often indeterminate, has been recovered from the Upper Cretaceous of New Jersey, Delaware, Maryland, Georgia, Montana, and Wyoming. The Peedee Formation (Maastrichtian) of North Carolina also contains hybodont sharks.

Order Lamniformes
Suborder Lamnoidea
Family Odontaspidae
Genus *Odontaspis* Agassiz, 1838
Odontaspis samhammeri Cappetta & Case, 1975
(Figures 4A-B)

Odontaspis samhammeri Cappetta & Case, 1975, p. 18, pl. 5, figs. 11-26.

Material: USNM 421719 (one anterior and one lateral tooth); NJSM 14143 (anterior teeth).

Description:

Lengths of the teeth of this odontaspid range from 1.0 cm to 1.8 cm. The central blade, along with the lateral denticles, is somewhat sigmoidal and triangular with no longitudinal striations observed. The central blade is curved lingually. Lateral and posterior teeth are compressed, with blades slanted towards the commissure (corners of the mouth), and with divergent roots.

Discussion:

The less common odontaspid can be easily distinguished from *Synodontaspis holmdelensis* by the absence of striations and a nutritive groove, and by its larger size. This species was first described from specimens recovered from the Navesink Formation of New Jersey (Capetta & Case, 1975). Its distribution elsewhere is not presently known, partly due to the ambiguity associated with odontaspid identification.

Genus *Synodontaspis* White, 1931
Synodontaspis holmdelensis (Cappetta & Case, 1975)
(Figures 5A-B)

Odontaspis holmdelensis Cappetta & Case, 1975, p. 19, pl. 6, figs. 10-21.

Material: NJSM 14610 (teeth).

Description:

Teeth are small in total length, ranging from 0.4 cm to 1.5 cm. Anterior teeth are somewhat lingually curved, convex, and striated, with a single lateral denticle on each side of the main blade connected by an enamel shoulder. Both the main blade and the denticles are sigmoidal. The root has two equal lobes separated on the lingual side by the nutritive groove at the medial boss. Lateral and posterior teeth are more compressed with broader and more flattened roots.

Discussion:

This is the more common odontaspid at Phoebus Landing and is the only odontaspid species with longitudinal striae on its lingual face. This species was first reported from the Upper Cretaceous in New Jersey and is also known from the Cretaceous of Delaware.

Family Lamnidae
Genus *Squalicorax* Whitley, 1939
Squalicorax kaupi (Agassiz, 1843)
(Figure 6A)

Corax kaupi Agassiz, 1843, p. 225, pl. 26A, figs. 25-34; pl. 26, figs. 4-8.

Material: USNM 421721 (teeth); NJSM 14007, 14009, 14275 (teeth).

Description:

The teeth of this shark are similar in shape to those of *S. kaupi* except that no notch is present on the crown. The teeth of *S. pristodontus* also tend to be larger than those of *S. kaupi*, with root widths ranging from 1.5 cm to 3.0 cm. Fine serrations are also present along the blade edge in this species.

Discussion:

This species is far less common than *S. kaupi* at Phoebus Landing, but comprises most of the larger specimens of the genus. *S. pristodontus* has also been reported from the Upper Cretaceous of New Jersey, Delaware, Maryland, and Wyoming; it is also known from the Peedee Formation of North Carolina.

Family Mitsukurinidae
Genus *Scapanorhynchus* Woodward, 1889
Scapanorhynchus texanus (Roemer, 1852)
(Figures 7A-D)

Lamna texanus Roemer, 1852, p. 29, pl. 2, fig. 7.

Material: USNM 421722-421724 (teeth); NJSM 14006, 14008, 14273, 14279 (teeth).

Description:

The teeth of this shark exhibit a great morphological variety. Both upper and lower jaw files have similar distributions of tooth forms. Both anterior and lateral teeth are generally large, ranging in length from 1.0 cm to 5.0 cm. Anterior teeth are elongated with bilateral roots. The recurved enamel blade possesses distinctive longitudinal striae on the convex lingual face. The roots are stout with a deep nutritive groove on the median boss in lingual aspect. Lateral teeth possess broad flattened blades, multiple lateral cusplets, and a somewhat flattened broad root. Often the cusplets are not present due to breakage. Striations are almost never present on lateral teeth except for a poorly developed region along the base of the enamel apron of the blade. The roots of lateral teeth are also medially grooved, but the groove is less pronounced than that of the anterior teeth. The posterior teeth resemble lateral teeth in form but possess flatter, more laterally divergent roots and much shorter and more slanted blades. The roots on posterior teeth are also medially grooved and the median boss is less pronounced than those anterior teeth.

Discussion:

This is by far the most common fish fossil recovered from Phoebus Landing. Identification of *Scapanorhynchus* teeth is complicated by their great morphological variety. This fossil shark is most closely related to the modern goblin shark, *Mitsukurina owstoni*, and comparison to the tooth distribution and placement of this shark has aided in the specific identification of the fossil form. *S. texanus* is also present in the Upper Cretaceous of New Jersey, Delaware, Maryland, Georgia, and Wyoming. Although Case (1979a) reported this genus as present in the Peedee Formation of North Carolina, he now believes it is possibly reworked from the underlying Black Creek Formation (Case, personal communication).

Order Squalomorpha
Suborder Squatinoidea
Family Squatinidae
Genus *Squatina* Duméril, 1806
Squatina hassei Leriche, 1929
(Figures 8A-C, 14E-G)

Squatina hassei Leriche, 1929, p. 206, figs. 1-3.

Material: USNM 421729 (tooth); NJSM 14614 (tooth).

Description:

Both teeth and the distinctive vertebrae of this shark have been recovered. The teeth are small, averaging 0.6 cm in height and 0.7 cm in basal width. The teeth possess a single medial blade which tilts lingually and extends down over the root, forming a distinct apron on the labial aspect. The root is slightly concave at the base and arches up, forming a triangular platform which accounts for approximately one-third of the total height of the tooth. Fenestrations may be present on the lingual aspect of the root but are not often apparent. Vertebrae have unequal ovoid faces with calcified cartilage surrounding the smaller anterior face.

Discussion:

These teeth of *Squatina* are quite rare and relatively difficult to find, partly due to their small size. *Squatina hassei* has been reported from the Upper Cretaceous of New Jersey, Delaware, Maryland, and Georgia.

Order Batoidea
Suborder Rajoidea
Family Sclerorhynchidae
Genus *Ischyrhiza* Leidy, 1856
Ischyrhiza mira Leidy, 1856
(Figures 9A-D, 10A-C)

Ischyrhiza mira Leidy, 1856c, p. 221; Fowler, 1911, pp. 167-168, fig. 103.

Material: USNM 421726 (rostral spines); NJSM 14011, 14167, 14263, 14265 (rostral spines), 14608 (oral tooth).

Description:

Both rostral spines and oral teeth of this sawfish have been recovered at Phoebus Landing. Rostral spines range in length from 1.0 to 3.5 cm. The rostral spines are elongated, with laterally compressed enamel blades and bony roots with an almost square cross-section at the base. The root, which represents approximately one-third of the total tooth length, is bilobed laterally with multigrooved prongs.

The oral teeth are extremely small and require fine screening to recover. They range in size from 0.3 cm to 0.6 cm in width and from 0.3 cm to 0.5 cm in height (Figure 4). Case (1978a, p. 196) describes the oral teeth as follows:

> "In the occlusal aspect, the crown is almost silhouetted against the root platform. The crown has a wide lateral buttress on either side of the central cusp, with border wrinkles of the labial edges of the buttress. There is a protruding and highly elevated cusp on the lingual aspect, and a thick apron overhanging the labial edge. In its labial view, the apron slopes downward posteriorly and butts up against a concavity on the lingual aspect of the tooth directly behind in the file. The root is bilobed. On the lingual aspect the root has two large foramina, one on either side of the concavity of the central crown. The exit canals from these foramina go through the medial groove of the basal aspect."

Discussion:

Oral teeth are far less commonly found that rostral spines partly due to their microscopic size. *Ischyrhiza mira* has been reported from both the Campanian and Maastrichtian of several states along the Atlantic Coastal Plain. This fish is found in Cretaceous deposits of New Jersey, Delaware, Maryland, Georgia, Montana, and Wyoming, as well as in the Peedee Formation of North Carolina.

Suborder Myliobatoidea
Family Dasyatidae

Genus *Rhombodus* Dames, 1881
Rhombodus levis Capetta & Case, 1975
(Figures 11A-C)

Rhombodus levis Capetta & Case, 1975, pp. 36-37, pl. 9, figs. 12-23.

Material: NJSM 14261 (pavement tooth).

Description:

Only one distinct type of pavement tooth from this ray-like fish has been recovered. Pavement teeth average 0.5 cm in height, width, and depth. The flattened, rhomboid, enamel-covered occlusal surface comprises the bulk of the tooth. The basal surface (root) is bilobed and approximately half as high as the occlusal "plate."

Discussion:

These teeth are small and can be overlooked unless collecting is done by fine screening. These teeth are reported from New Jersey, Delaware, and Georgia. *Rhombodus* cf. *R. binkhorsti* has been recovered from the Peedee Formation of North Carolina.

Family Myliobatidae
Genus *Brachyrhizodus* Romer, 1942
Brachyrhizodus wichitaensis Romer, 1942
(Figures 12A-F)

Brachyrhizodus wichitaensis Romer, 1942, p. 221, pl. 1, figs. 7-8.

Material: USNM 421718 (pavement teeth); NJSM 14010 (pavement teeth).

Description:

Both central and lateral pavement teeth of this ray have been recovered. The central pavement teeth average 2.0 cm in length, 1.0 cm in width, and 1.0 cm in height. The lateral pavement teeth have dimensions which are approximately one-half that of the central teeth. The pavement teeth are laterally elongate and hexagonal in occlusal outline. The occlusal surface (top), which is enamel-covered and convex, often exhibits numerous shallow cracks and pits. The basal surface is a solid, dense bony material, slightly concave, and randomly divided into two or more root lobes which are not always symmetrical (evenly partitioned).

Discussion:

The pavement teeth of this ray exhibit a great variety, especially in size and root lobe arrangement. This ray has been reported from New Jersey, Delaware, and Georgia. The range of this species is Campanian-Maastrichtian (Case, personal communication).

Subclass Holocephalii
Order Chimaeriformes

Family Chimaeridae
Genus *Ischyodus* Egerton, 1843
Ischyodus cf. *I. bifurcatus* Case, 1978
(Figures 13A-C)

Ischyrhodus bifurcatus Case, 1978b, pp. 22-25, figs. 1-5, pl. 1.

Material: NJSM 14262 (mandibular plate fragments), 14177 (mandibular plate fragments?), 14040 (fin spine fragment).

Description:

The "tooth-plates" of these fish are trapezoidal bony jaw segments which exhibit two obliquely parallel channels of tubular dentine called tritors which serve as the masticating surfaces. These fossils are fragile and are usually recovered broken and irregular in shape; fragments generally measure approximately 3.0 to 4.0 cm in length. Dorsal fin spines have also been recovered. The spines have smooth lateral faces without ornamentation, and a single linear row of curved "tooth-like" projections on the posterior face. Although slightly smaller in size, these spines superficially resemble spines of *Hybodus* (see above).

Discussion:

Chimaeroid fish possess a masticating structure in which the lower jaw is composed of two mandibular plates which fuse at the symphesis, and the upper jaw is composed of a pair of palatine plates and a pair of vomerine plates. Both the mandibular plates and the palatine plates have tritors. Therefore, fairly complete specimens are required to determine specific identifications. Patterson (1965) and Garman (1904) discuss the anatomy of certain chimaeroids, and their works may be useful for the purpose of mouthplate identification. The dorsal fin spines are tentatively assigned to this species since no other chimaeroids have been recovered, although the spines themselves do not appear to be diagnostic for specific identification (Case, 1978b, p. 24). *Ischyodus bifurcatus* has also been reported from Montana (Case, 1979b) and Wyoming (Case, 1987), and was originally described from the Upper Cretaceous of New Jersey (Case, 1978b). Chimaeroid fishes are widespread throughout the Late Cretaceous and in the Early Eocene, but are not abundant in modern ocean faunas.

Chondrichthyes indet.
(Figures 14-17)

Both laterally and compressed round selachian vertebral centra and oval batoid vertebral centra have been recovered (Figure 14). Sections of calcified cartilage which exhibit a very fine tubular ultrastructure are also found (Figure 15). Two distinct types of coprolites can be identified, although this may be a function of their deposition. Both types exhibit the spiral chambering which is a result of the chondrichthyan intestine. One type is cylindrical in appearance (Figure 16), whereas the other variety is compressed or flattened. The flattening may be due to redeposition. Also recovered are dermal denticles which probably belong to batoids in the fauna (Figure 17). Cappetta &

Case (1975, pl. 9, figs. 21-23) figure similar denticles, referring them to *Rhombodus levis*; however, Case (1987, text-fig. 12c) tentative identifies them as *Brachyrhizodus wichitaensis.*

Class Osteichthyes
Subclass Actinopterygii
Order Lepisosteiformes
Family Lepisosteidae
Lepisosteidae indet.
(Figures 18A-B)

Material: USNM 421720 (scale), 421717 (tooth); NJSM 14024, 14271 (scales), 14025 (premaxillary teeth).

Description:

Scales and isolated teeth which can be assigned to the gar family Lepisosteidae are infrequently encountered at Phoebus Landing. The scales, which are typical of garfish, generally do not exceed 1.5 cm in length and are rhomboidal in shape with an enameled outer surface. The underside of the scale is of a layered bony composition (ganoid ivory). The enameled surface exhibits annuli and regions that are speckled with minute pores.

The isolated teeth are curved, very slender, conical crowns usually devoid of roots. These range in length from 0.5 cm to 1.2 cm. The teeth are not striated nor do they exhibit any longitudinal ribs or keels. Although sometimes flat, a concave base can often be noted on these teeth; they are distinctive, as they have enamel only at the tip of the tooth.

Discussion:

What may possibly be a Cretaceous gar from the Atlantic Coastal Plain was figured by Fowler (1911, pp. 150-151) when he described *Lepisosteus knieskerni* (ANSP 2264) from Monmouth County, New Jersey. This taxon, however, is suspect, since the species is described from an indeterminate scale with questionable locality data.

Although the recovered specimens without doubt exhibit the characteristics of the Lepisosteidae, it is doubtful whether a more specific level of identification is possible with the material at hand. The lack of fossil evidence of frontal bones or premaxillas from Phoebus Landing precludes identifying the gar material even to genus since both *Lepisosteus* and *Atractosteus* exhibit similar characteristics otherwise. Wiley (1976) provides a complete phylogeny of both fossil and recent gars for future reference should more complete gar material be recovered.

Order Pycnodontiformes
Family Pycnodontidae
Genus *Anomoeodus* Forir, 1887
Anomoeodus phaseolus (Hay, 1899)

Pycnodus phaseolus Hay, 1899, p. 788 (based on Leidy, 1873)
Pycnodus faba Leidy (nec Meyer), 1873, pp. 292, 349, pl. 19, figs. 15-16.

Material: NJSM 14731 (crusher tooth).

Description:

Most commonly found are the isolated crusher teeth, along with the splenial jaw sections. The crusher teeth may appear round, oval, or elongated in occlusal view. The occlusal view exhibits a totally smooth convex surface whereas the basal perspective features a deeply excavated pulp cavity. The splenial jaw sections or dentary batteries contain a medial row of elongated teeth with round or oval teeth on the lateral margins. The medial row of elongated teeth parallel each other and are often evenly matched by the smaller lateral teeth.

The elongated medial teeth average 2.5 cm in length and 0.7 cm in width. Lateral teeth average 0.7 cm in diameter and exhibit no sculpturing on the surface, although both the medial and lateral crusher teeth sometimes contain pits on their occlusal surfaces. Also recovered are the vomerine batteries which exhibit crusher teeth that are oval to round in occlusal view.

Discussion:

Anomoeodus phaseolus has a widespread distribution throughout the Cretaceous sediments of the Atlantic Coastal Plain. This species has been reported from the Campanian of New Jersey, Delaware, Maryland, South Carolina, and Georgia. This fish is also present in the Peedee Formation (Maastrichtian) of North Carolina.

Division Teleostei
Order Ichthyodectiformes
Family Ichthyodectidae
Genus *Xiphactinus* Leidy, 1870
Xiphactinus audax Leidy, 1870
(Figures 20A-C)

Xiphactinus audax Leidy, 1870, p. 12; 1873, pp. 290, 348, pl. 17, figs. 9-10.

Material: NJSM 14144, 14176 (teeth).

Description:

Teeth are large, some reaching 5.5 cm with most over 3.0 cm in blade length. The enamel blades of the teeth are no striated or grooved in any fashion; they are oval in cross-section. Large pulp cavities at the base of the teeth are caused by the development of a seed tooth below the functional one. The teeth vary greatly in size and placement in the jaw, with the anterior teeth being slightly larger than the posterior. The maxillary fangs (anterior) are the largest blades. According to Stewart (1900), tooth placement cannot be used as an identifying characteristic for differentiating between species of *Xiphactinus*. The vertebrae of this fish are nearly round in posterior and anterior views and are deeply grooved in lateral aspect. Bardack (1965) provides a detailed discussion of *X. audax*.

Discussion:

These fossils comprise the largest bony fish teeth recovered at Phoebus Landing, although the anterior teeth of *Enchodus*

very closely rival the size of *Xiphactinus* teeth. Care must be taken not to confuse these large bony-fish teeth with the teeth of some of the associated Cretaceous reptiles. Plesiosaur (*Cimoliasaurus*) teeth resemble the teeth of this fish but posses distinct longitudinal grooves which the fish teeth lack. This fish has also been recovered from the Campanian of New Jersey, Delaware, and Georgia, with several species having been reported from the Cretaceous chalk of Kansas (Coniacian).

Family Saurodontidae
Genus *Saurodon* Hays, 1830
Saurodon sp.
(Figures 21A-C)

Material: USNM 392103 (anterior dentary fragment).

Description:

Only one occurrence of *Saurodon* has been documented from Phoebus Landing. The specimen, an anterior dentary fragment without teeth, was recovered by Frank and Becky Hyne of Greenville, North Carolina, who subsequently donated the specimen to the National Museum of Natural History of the Smithsonian Institution. The specimen, which is too fragmentary to identify to the specific level, is the first recorded occurrences of this fish in North Carolina.

Saurodon possesses a toothed maxilla and dentary. The teeth are laterally compressed enamel blades with slightly striated bases. The teeth of the Hyne specimen might have averaged approximately 0.5 cm in length. The most interesting characteristic of this fish is the presence of a long, pointed, triangular predentary which attaches to the anterior end of the dentary.

Discussion:

Saurodon has also been recovered from the Cretaceous of New Jersey, and several species have been described from the Kansas chalks.

Order Elopiformes
Suborder Albuloidei
Family Albulidae
Genus *Albula* Bloch & Schneider, 1801
Albula sp.
(Figures 22A-B)

Material: NJSM 14613 (crusher tooth).

Description:

Isolated crusher-tooth caps are roughly round in occlusal view with a distinctive concentric terracing on the occlusal surface. These teeth average 0.3 cm in diameter and possess a concave pulp cavity on the basal aspect.

Discussion:

The teeth of this fish are rare, partly due to their microscopic size. No mouthplates which can definitely be assigned to this fish have been recovered. *Albula* sp. has also been reported from the Blufftown Formation (Campanian) of Georgia.

Family ?Phyllodontidae
Genus *Paralbula* Blake, 1940
Paralbula casei Estes, 1969
(Figures 22C-D)

Paralbula casei Estes, 1969, pp. 323-324, figs. 3, 6c-e.

Material: ANSP 15312 (mouthplate); NJSM 14264 (mouthplate).

Description:

The most commonly recovered parts of this fish are isolated crusher teeth. The teeth are small, averaging 0.25 cm in diameter. Individual teeth are round or slightly oval, with a shallow concave pulp cavity and a convex occlusal surface which has a thin enamel covering. The occlusal surfaces of these teeth have faintly developed, but coarse and radially positioned, sculpturing. This ornamentation serves to differentiate these teeth from those of *Anomoeodus phaseolus* (see above). The mouthplates of this fish, typical of the phyllodonts, are oval in outline and exhibit irregularly placed but uniformly sized teeth. Estes (1969) provides a detailed description of *Paralbula*.

Discussion:

Fossils of this fish are rare at Phoebus Landing, and only fine screening has produced specimens. This fish is also known from the Upper Cretaceous sediments of New Jersey, Delaware, and Georgia.

Order Aulopiformes
Suborder Enchodontoidei
Family Enchodontidae
Genus *Enchodus* Agassiz, 1835
Enchodus cf. *E. petrosus* Cope,1874
(Figures 23A-E)

Tetheodus pephredo Cope,1874, p. 43.
Enchodus petrosus Cope,1874, p. 44.

Material: NJSM 14148 (isolated palatine fang).

Description:

Upper and lower jaws differ slightly in this fish, but contain several similar characteristics. The upper jaw contains a large palatine tooth (fang) near the symphysis, along with alternating larger and smaller teeth which gradually taper towards the posterior. The mandible also possesses a large tooth just posterior to the symphysis which is about twice as large as the other dentary teeth but which is still smaller than the palatine tooth. The remaining teeth in the mandible are relatively small with minimal alteration of size, and also taper in length towards the posterior of the jaw. According to Stewart (1900, pp. 373-380), the irregular tooth size and placement in the jaw may be

used as a differentiating characteristic between various species of this fish.

Isolated palatine teeth possess a convex smooth enamel anterior surface and a strongly convex longitudinally striated posterior surface which is often slightly concave at the base. These teeth are long and relatively slender, being broadest at the base of the tooth. The palatine teeth range in length from 1.0 cm to 5.0 cm. These teeth are commonly found attached to a section of palatine bone (Figure 23A). Lateral jaw sections with several teeth may also be recovered and often exhibit the alternating larger and smaller teeth. The vertebrae of the fish exhibit deep lateral concavities. Goody (1976) provides a detailed description of *E. petrosus* and its relationship to the other members of this genus.

Discussion:

Enchodus is a widely distributed Cretaceous fish, found worldwide. The genus has been reported from the Atlantic Coastal Plain in New Jersey, Delaware, Maryland, South Carolina, and Georgia. *E. ferox* is the common Maastrichtian representative of this fish in the Atlantic Coastal Plain; it is also present in the Peedee Formation of North Carolina.

Order Perciformes
Suborder Scrombroidei
Xiphioidei *Incertae Sedis*
Genus *Cylindracantus* Leidy, 1856
Cylindracanthus ornatus Leidy, 1856
(Figures 24A-B)

Cylindracanthus ornatus Leidy, 1856a, p. 12; Fowler, 1911, pp. 141-142, fig. 87 (1-10).

Material: Author's collection.

Description:

Longitudinally grooved or striated, gradually tapering, cylindrical fossils assigned to *Cylindracanthus ornatus* are infrequently recovered. There are approximately 40 longitudinal grooves or striae on the circumference, although considerable variation has been noted within the species (Fowler, 1911, p. 142). The fossils are nearly circular in cross-section. Although not noted on the few specimens recovered from Phoebus Landing, they sometimes exhibit centrally radiating fissures and a pair of lateral nutrient canals. The longest specimen recovered, which was a fragmentary section, measures 3.2 cm in length and 1.0 cm in diameter.

Discussion:

These fossils are rare at Phoebus Landing and all of the specimens recovered have been fragmentary. The anatomical position of these fossils is uncertain; both rostra and fin spines have been suggested as the body location, although fin spines are favored (Fierstine, 1974, p. 43). The taxonomic position of this group is also uncertain; it has been placed by Fierstine (1974) within Xiphioidei *Incertae Sedis*. Fossils of *Cylindracanthus* have also been recovered from the Cretaceous sediments of New Jersey and the Eocene deposits of North Carolina.

Order Pleuronectiformes
Suborder Tetraodontoidei
Family Trigonodontidae
Genus *Stephanodus* Zittel, 1883
Stephanodus sp.
(Figures 25A-B)

Material: USNM 421730 (pharyngeal tooth); NJSM 14033 (pharyngeal tooth).

Description:

Small sickle-shaped pharyngeal teeth of this fish have been recovered. Relatively complete teeth with root structures average 1.0 cm in height and 0.5 cm in width, although most specimens are recovered without any root attachment and average 0.4 cm in height. The laterally compressed teeth are virtually flat, with a blade that is inclosed in an enamel sheath which extends down into the bony root. The blade and root are approximately the same size, dividing the teeth into two equal parts.

Discussion:

These small teeth are rare, partly due to the methods of collecting at the locality, although several have been recovered through fine screening. The teeth recovered very closely resemble the Eocene form, *Eotrigonodon serratus* Gervais, which Nolf (1970) describes from Belgium. *Stephanodus* has also been reported from the Cretaceous sediments of New Jersey, Delaware, Maryland, and Georgia.

Osteichthyes indet.
(Figure 26)

Fish vertebrae ranging in size from 0.5 cm to 4.0 cm have been found along with small isolated sections of porous, fragile fish bone. Most interesting is the presence of fish coprolites; they have a great variation in size, but average 1.5 cm in length; they are small masses, tubular in shape.

Conclusions

Due to the depositional circumstances at Phoebus Landing, the relative abundance of certain species most likely does not reflect a typical in-place living faunal assemblage for the locality during Black Creek time. The preserved fauna instead reflects environmental factors at the source areas contributing material for deposition at the Phoebus Landing site. Some constituents of the fauna appear to be reworked. It is expected that terrestrial deposits of Black Creek age would be dominated by dinosaur and crocodilian remains, and that distinctly marine deposits would contain predominantly fish and marine reptiles. The fossil fauna at Phoebus Landing is a heterogeneous mixture containing all of these vertebrate groups.

Members of the group Chondrichthyes comprise 96 percent of the fish fossils recovered from Phoebus Landing, with only 4 percent representing the Osteichthyes (Table 4). *Scapanorhynchus texanus* heavily dominates the fish fauna, accounting for more than 79 percent of the total number of fish fossils. *Squalicorax kaupi* and *S. pristodontus* combined comprise slightly more than 8 percent of the total fish fossils. No members of the osteichthyan fauna accounted for more than 1 percent of the total number of fish fossils recovered.

The relative abundance of specimens at Phoebus Landing is significantly different from the distributions reported from other coastal plain Campanian faunas. Lauginiger (1986, p. 55) reports that *Squalicorax* sp. is the dominant fish fossil (approximately 51 percent) in the Upper Campanian at Big Brook, Monmouth County, New Jersey, followed by *Scapanorhynchus texanus* (approximately 17 percent). It is likely that the fauna presented by Lauginiger is a mixture of both Campanian and Maastrichtian elements. Schwimmer (1986, p. 116) reports that *Scapanorhynchus texanus* accounts for more than 90 percent of the fish material in the Blufftown Formation (Campanian) of western Georgia, followed by *Ischyrhiza mira* and *Xiphactinus audax*. These differences may be due to environmental factors.

The fish fauna of the Black Creek Formation of North Carolina exhibits a diversity in the number of taxa which equals that of the Maastrichtian faunas of New Jersey, Delaware, Maryland, Georgia, Texas, Montana, and Wyoming. The Black Creek fauna differs distinctly from the fish fauna of the Peedee Formation (Late Maastrichtian) of North Carolina as reported by Case (1979a). The Peedee, lying stratigraphically above the Black Creek, contains several selachians not present in the Black Creek.

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References Cited

AGASSIZ, L. 1843. *Recherches sur les poissons fossils* [1833-1845]. Vol. 3. Neuchatel, 390 pp.

BAIRD, D., & J. R. HORNER. 1979. Cretaceous dinosaurs of North Carolina. *Brimleyana*, 2:1-29.

BARDACK, D. 1965. Anatomy and evolution of chirocentrid fishes. *University of Kansas, Paleontological Contributions, Vertebrata*, art. 10, pp. 1-88.

BRETT, C. E., & W. H. WHEELER. 1961. A biostratigraphic evaluation of the Snow Hill Member, Upper Cretaceous of North Carolina. *Southeast Geology*, 3(2):49-132.

CAPPETTA, H. 1987. Elasmobranchii II, Mesozoic and Cenozoic selachians. *Handbook of Paleoichthyology*, Vol. 3B. Stuttgart: Gustave Fischer, pp. 1-193.

CAPPETTA, H., & G. R. CASE. 1975. Contribution a l'etude des selaciens du groupe Monmouth (Campanian-Maestrichtien) du New Jersey. *Palaeontographica*, Abt. A, 151:1-46.

CARROLL, R. 1988. *Vertebrate Paleontology and Evolution*. W. H. Freeman and Co., 698 pp.

CASE, G. R. 1978a. A new selachian fauna from the Judith River Formation (Campanian) of Montana. *Palaeontographica*, Abt. A, 160:176-205.

-------. 1978b. *Ischyodus bifurcatus*, a new species of Chimaeroid fish from the Upper Cretaceous of New Jersey. *Geobios*, 11(1):21-29.

-------. 1979a. Cretaceous selachians from the Peedee Formation (Late Maestrichtian) of Duplin County, North Carolina. *Brimleyana*, 2:77-89.

-------. 1979b. Additional fish records from the Judith River Formation (Campanian) of Montana. *Geobios*, 12(2):223-233.

-------. 1987. A new selachian fauna from the Late Campanian of Wyoming (Teapot Sandstone Member, Mesaverde Formation, Big Horn Basin). *Palaeontographica*, Abt. A, 197:1-37.

CASE, G. R., & D. R. SCHWIMMER. 1988. Late Cretaceous fish from the Blufftown Formation (Campanian) in western Georgia. *Journal of Paleontology*, 62(2):290-301.

COPE, E. D. 1871. Observations on the distribution of certain extinct Vertebrata in North Carolina. *American Philosophical Society, Proceedings*, 12:210-216.

-------. 1874. Review of the Vertebrata of the Cretaceous Period found west of the Mississippi River. *U.S. Geological and Geographical Survey of the Territories, Bulletin 1*, pp. 3-48.

-------. 1875. Synopsis of the Vertebrata whose remains have been preserved in the formations of North Carolina. *North Carolina Geological Survey, Report* 1:29-5.

EMMONS, E. 1858. Agriculture of the eastern counties; together with descriptions of the fossils of the marl beds. *North Carolina Geological Survey*, 314 pp.

ESTES, R. 1969. Studies on fossil phyllodont fishes: interrelationships and evolution in the Phyllodontidae (Albuloidei). *Copeia*, 2:317-331.

FIERSTINE, H. L. 1974. The paleontology of billfish--the state of the art. *In*: R. S. Shomura & F. Williams (eds.), *Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972. Part 2, Review and contributed papers*. NOAA Technical Report NMFS SSRF-675, pp. 34-44.

FOWLER, H. W. 1911. *A description of the fossil fish remains of the Cretaceous, Eocene, and Miocene formations of New Jersey*. New Jersey Geological Survey, Bulletin 4, 192 pp.

GALLAGHER, W. B., D. C. PARRIS, & E. E. SPAMER. 1986. Paleontology, biostratigraphy, and depositional environments of the Cretaceous-Tertiary transition in the New Jersey Coastal Plain. *The Mosasaur*, 3:1-35.

GARMAN, S. 1904. The chimaeroids (Chismopnea Raf., 1815; Holocephala Mull., 1834), especially *Rhinochimaera* and its allies. *Harvard University, Museum of Comparative Zoology, Bulletin*, 41(2):247-272.

GOODY, P. 1976. *Enchodus* (Teleostei: Enchodontidae) from the Upper Cretaceous Pierre Shale of Wyoming and South Dakota with an evaluation of the North American enchodontid species. *Palaeontographica*, Abt. A, 152:91-112.

HARTSTEIN, E. F. & L. E. DECINA. 1986. A new Severn Formation (Early Middle Maastrichtian, Late Cretaceous) locality in Prince Georges County, Maryland. *The Mosasaur*, 3:87-95.

HAY, O. P. 1899. On some changes in the names generic and specific of certain fossil fishes. *American Naturalist*, 33:783-792.

Table 4.

Comparative abundance of fish fauna at Phoebus Landing, North Carolina.

	Number of Specimens	Percent of Group	Percent of Total Fauna
Class Chondrichthyes			
Hybodus montanensis (spines)	2	0.10	0.10
Hybodus sp. (spines)	8	0.41	0.40
Hybodus sp. indet. (teeth)	21	1.09	1.05
Hybodus sp. indet. (cephalic hooks)	5	0.26	0.25
Odontaspis samhammeri (teeth)	6	0.31	0.30
Synodontaspis holmdelensis (teeth)	11	0.57	0.55
Squalicorax kaupi (teeth)	129	6.69	6.43
S. prisodontus (teeth)	32	1.66	1.59
Squalicorax sp. indet. (teeth)	9	0.47	0.45
Scapanorhynchus texanus (teeth)	1589	82.42	79.17
Squatina hassei (teeth)	6	0.31	0.30
S. hassei (vertebrae)	2	0.10	0.10
Ischyrhiza mira (oral teeth)	4	0.21	0.20
I. mira (rostral spines)	48	2.49	2.39
Rhombodus levis (pavement teeth)	6	0.31	0.30
Brachyrhizodus wichitaensis (pavement teeth)	12	0.62	0.60
Ischyodus cf. *I. bifurcatus* (jaw sections)	2	0.10	0.10
Selachian vertebrae (not *Squatina*)	8	0.41	0.40
Batoid vertebrae	7	0.36	0.35
Batoid(?) dermal denticle	1	0.05	0.05
Calcified cartilae segments	7	0.36	0.35
Coprolites	13	0.67	0.65
Total for Group	1928	99.97	96.08
Class Osteichthyes			
Lepisosteidae indet. (teeth)	3	3.80	0.15
Lepisosteidae indet. (scales)	3	3.80	0.15
Anomoeodus phaseolus (crusher teeth)	14	17.72	0.70
A. phaseolus (jaw sections)	1	1.27	0.05
Xiphactinus audax (teeth)	10	12.66	0.50
X. audax (vertebrae)	1	1.27	0.05
Saurodon sp.	*	*	*
Albula sp. (crusher teeth)	1	1.27	0.05
Paralbula casei (crusher teeth)	2	2.53	0.10
P. casei (mouthplate)	1	1.27	0.05
Enchodus cf. *E. petrosus* (teeth)	16	20.25	0.80
E. cf. *E. petrosus* (jaw section)	4	5.06	0.20
Cylindracanthus ornatus (?spines)	2	2.53	0.10
Stephanodus sp. (pharyngeal teeth)	6	7.59	0.30
Coprolites	2	2.53	0.10
Indeterminate vertebrae	11	13.92	0.55
Indeterminate bone fragments	2	2.53	0.10
Total for Group	79	100.00	3.95
Grand Total of Fish Fauna	2007		100.03

*Only one specimen known (USNM 392103)

HERON, D. S., Jr., & W. H. WHEELER. 1964. The Cretaceous formations along the Cape Fear River, North Carolina. *Atlantic Coastal Plain Geological Association, Field Conference Guidebook* 5, pp. 1-55.
LAUGINIGER, E. M. 1986. An Upper Cretaceous vertebrate assemblage from Big Brook, New Jersey. *The Mosasaur*, 3:53-61.
LAUGINIGER, E. M., & E. F. HARTSTEIN. 1983. *A guide to fossil sharks, skates, and rays from the Chesapeake and Delaware Canal area*. Delaware Geological Survey, Open-File Report 21, 64 pp.
LEIDY, J. 1856a. Descriptions of two ichthyodorulites. *Academy of Natural Sciences of Philadelphia, Proceedings*, 8:11-12.
-------. 1856b. Notices of extinct vertebrated animals discovered by Prof. E. Emmons. *Academy of Natural Sciences of Philadelphia, Proceedings*, 8:255-256.
-------. 1856c. Notices on the remains of extinct vertebrate animals of New Jersey collected by Cook of the State Geological Survey under the direction of Dr. W. Kitchell. *Academy of Natural Sciences of Philadelphia, Proceedings*, 8:221.
-------. 1870. Remarks on the ichthyodorulites from Kansas and Tennessee and on the mammalian remains from Illinois. *Academy of Natural Sciences of Philadelphia, Proceedings*, 22:12-13.
-------. 1873. *Contributions to the extinct vertebrate faunas of the western territories*. U.S. Geological and Geographical Survey of the Territories [Hayden], Vol. 1, 358 pp.
LERICHE, M. 1929. Les poissons du Cretace marin de la Belgique et du Limbourg Hollandais. *Bulletin de Societe du Belge de Geologie, Paleontlogie, et d'-Hydrologie*, 37:199-299.
MILLER, H. W. 1966. Cretaceous vertebrate faunas from Phoebus Landing, North Carolina. *Elisha Mitchell Scientific Society, Journal*, 82(2):1.
-------. 1967. Cretaceous vertebrates from Phoebus Landing, North Carolina. *Academy of Natural Sciences of Philadelphia, Proceedings*, 119(5):219-235.
-------. 1968. Additions to the Upper Cretaceous vertebrates from Phoebus Landing, North Carolina. *Elisha Mitchell Scientific Society, Journal*, 84(4):467-471.
NOLF, D. 1970. Sur la fauna ichthyologique d'un falun dans l'argile des Flandres, Pres de Courtrai (Belgique). *Bulletin de Societie du Belge Geologie, Paleontologie et d'Hydrologie*, 79(1):11-24.
PATTERSON, C. 1965. The phylogeny of the chimaeroids. *Royal Society of London, Philosophical Transactions*, Pt. B, 249:101-219.
PARRIS, D. C., B. GRANDSTAFF, R. DENTON, W. B. GALLAGHER, C. DETAMPLE, S. S. ALBRIGHT, E. E. SPAMER, & D. BAIRD. 1987. *Taphonomy of the Ellisdale dinosaur site, Cretaceous of New Jersey (Final report on National Geographic Grant 3299-86)* [unpublished].
PURDY, R. W. 1984. A key to the common genera of Neogene shark teeth; appendix to Fossil fishes of the Calvert and Eastover Formations. *In*: L. W. Ward & K. Kraft (eds.), *Stratigraphy and paleontology of the outcropping Tertiary beds in the Pamunkey River region, central Virginia Coastal Plain*. Atlantic Coastal Plain Geological Association, Guidebook for 1984 fieldtrip, pp. 210-215.
RICHARDS, H. G. 1950. Geology of the coastal plain of North Carolina. *American Philosophical Society, Transactions*, new series, 40(1):1-83.
ROEMER, A. 1852. *Die Kriedelbildingen von Texas und ihre organisschen einschulusse*. Vol. 6. Bonn: Ab. Marcus, 100 pp.
ROMER, A. S. 1942. Notes on certain Paleozoic fishes. *American Journal of Science*, 240:216-229.
-------. 1966. *Vertebrate paleontology*. Chicago: University of Chicago Press, 3rd ed., 468 pp.
SCHWIMMER, D. R. 1986. Late Cretaceous fossils from the Blufftown Formation (Campanian) in western Georgia. *The Mosasaur*, 3:109-123.
SOHL, N. F., & R. A. CHRISTOPHER. 1983. *The Black Creek-Peedee formational contact (Upper Cretaceous) in the Cape Fear region of North Carolina*. U.S. Geological Survey Professional Paper 1285, 37 pp.
STEPHENSON, L. W. 1912. The Cretaceous formations. *In*: W. B. Clark et al., *The Coastal Plain of North Carolina*. North Carolina Geological and Economic Survey, Vol. 3, pp. 73-171.
-------. 1923. *The Cretaceous formations of North Carolina*. North Carolina Geological and Economic Survey, Vol. 5, 604 pp.
STEWART, A. 1900. Teleosts of the Upper Cretaceous. *Geological Survey of Kansas*, 6(2):257-403.
WILEY, E. O. 1976. *The phylogeny and biogeography of fossil and recent gars (Actinopterygii: Lepisosteidae)*. University of Kansas, Museum of Natural History, Miscellaneous Publication 64, 111 pp.

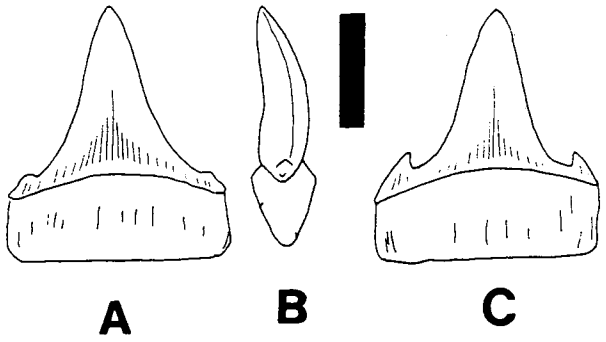

Figure 1. Hybodont shark teeth. **A, B,** *Hybodus montanensis*: **A,** lingual view; **B,** profile view. **C,** *Hybodus* sp., lingual view. Scale in centimeters.

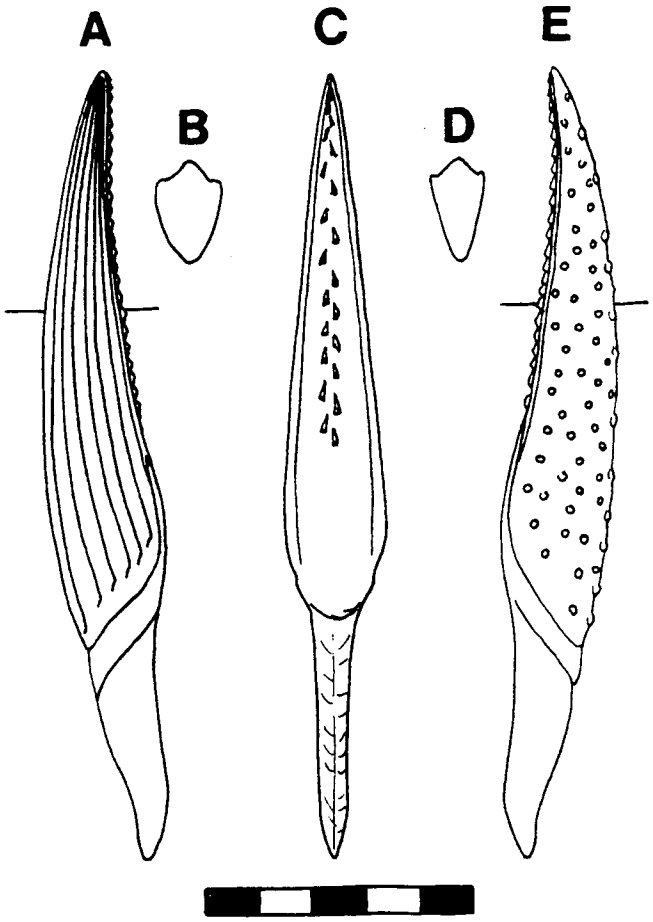

Figure 2. Hybodont shark dorsal fin spines. **A-C,** *Hybodus montanensis*: **A,** lateral view; **B,** cross-section at point marked in A; **C,** posterior view. **D-E,** *Hybodus* sp.: **D,** cross-section at point marked on E; **E,** lateral view. Scale in centimeters.

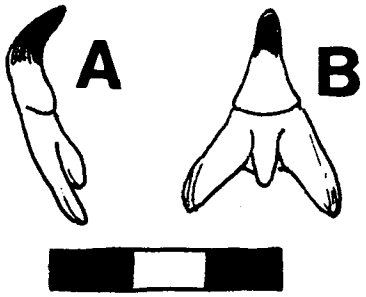

Figure 3. Cephalic clasper hook of *Hybodus* sp. **A**, profile view; **B**, ventral view. Scale in centimeters.

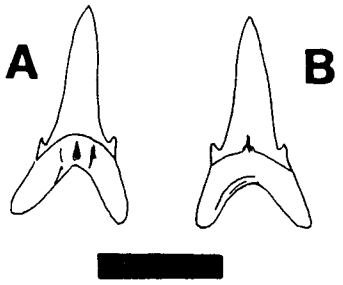

Figure 4. Tooth of *Odontaspis samhammeri*. **A**, lingual view; **B**, labial view. Scale in centimeters.

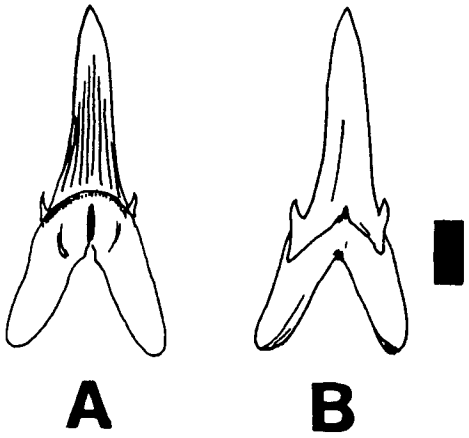

Figure 5. Tooth of *Synodontaspis holmdelensis*. **A**, lingual view; **B**, labial view. Scale in centimeters.

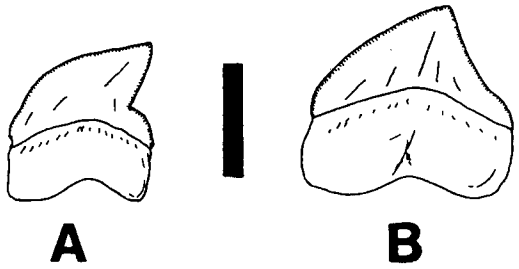

Figure 6. Teeth of *Squalicorax*. **A**, *S. kaupi*, lingual view; **B**, *S. pristodontus*,

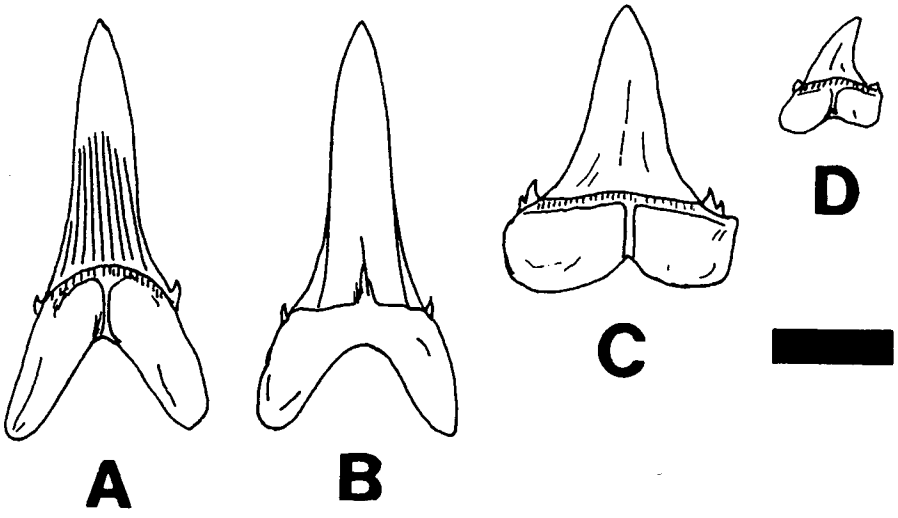

Figure 7. Teeth of *Scapanorhyncus texanus*. **A**, anterior tooth, lingual view; **B**, anterior tooth, labial view; **C**, lateral tooth, lingual view; **D**, posterior tooth, lingual view. Scale in centimeters.

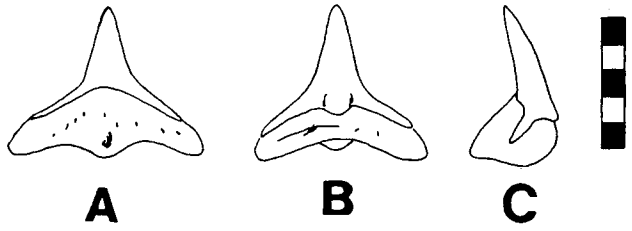

Figure 8. Tooth of *Squatina hassei*. A,lingual view; B, labial view; C, profile view. Scale in millimeters.

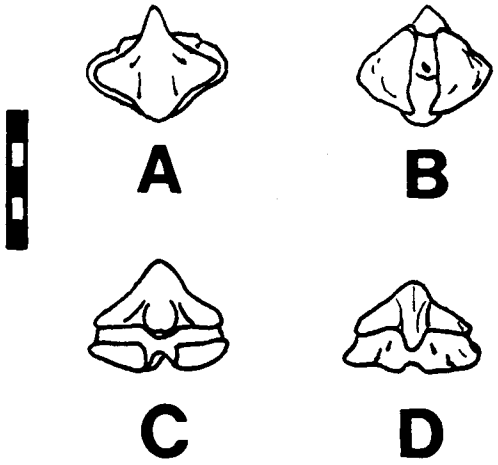

Figure 9. Oral tooth of *Ischyrhiza mira*. A, occlusal view; B, basal view; C, labial view; D, lingual view. Scale in millimeters.

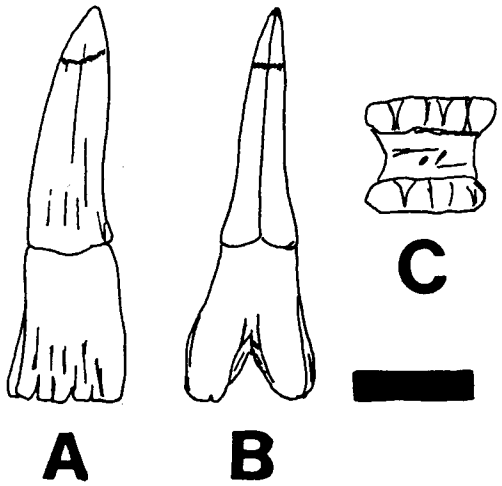

Figure 10. Rostral spines of *Ischyrhiza mira*. A, dorsal/ventral view; B, anterior/posterior view; C, basal view. Scale in centimeters.

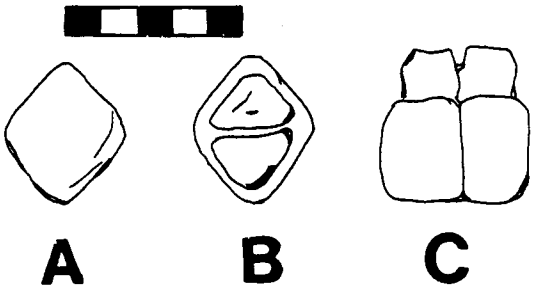

Figure 11. Pavement tooth of *Rhombodus levis*. A, occlusal surface; B, basal surface; C, lateral view. Scale in millimeters.

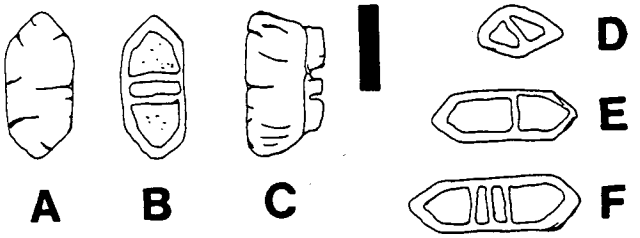

Figure 12. Pavement teeth of *Brachyrhizodus wichitaensis*. A, central tooth, occlusal surface; B, central tooth, basal surface; C, central tooth, labial/lingual view; D, lateral tooth, basal surface; E, central tooth, basal surface; F, central tooth, basal surface. Scale in centimeters.

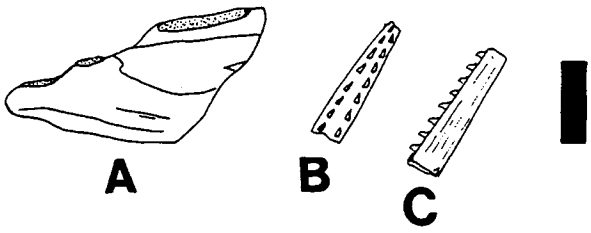

Figure 13. *Ischyodus* cf. *I. bifurcatus*. A, right-hand mandible; B, fin spine fragment, posterior view; C, fin spin fragment, lateral view. Scale in centimeters.

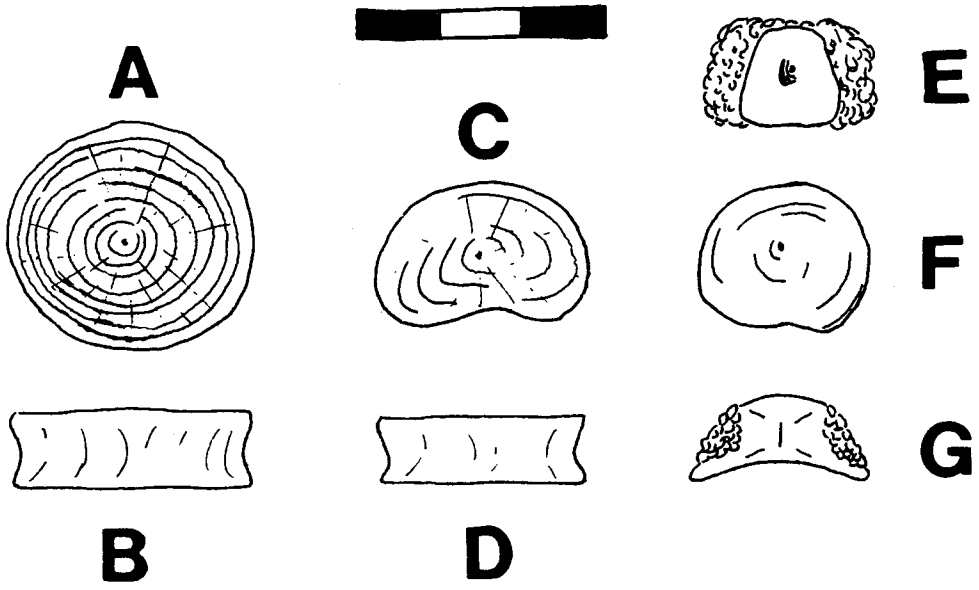

Figure 14. Chondrichthyan vertebral centra. A-B, selachian vertebral centra: A, anterior/posterior face; B, dorsal/ventral view. C-D, batoid vertebral centra: C, anterior/posterior face; D, dorsal/ventral view. E-G, vertebral centra of *Squatina*: E, anterior face; F, posterior face; G, ventral view. Scale in centimeters.

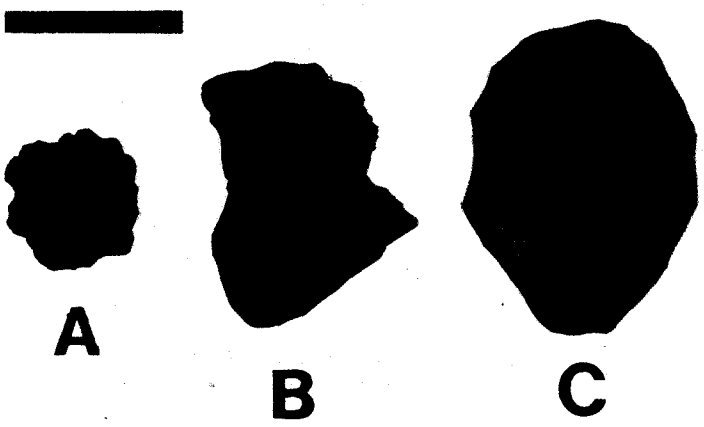

Figure 15. A-B, calcified cartilage sections of *?Ischyrhiza* sp. C, dermal denticle, surficial view, of *?Brachyrhizodus* sp. Scale in centimeters.

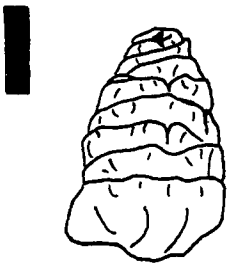

Figure 16. Chondrichthyan coprolite. Scale in centimeters.

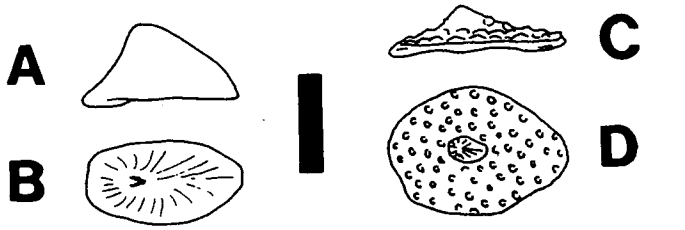

Figure 17. Chondrichthyan dermal denticles. A-B, *?Rhombus* sp.: A, lateral view; B, surficial view. C-D, *?Brachyrhizodus* sp.: C, lateral view; D, surficial view. Scale in centimeters.

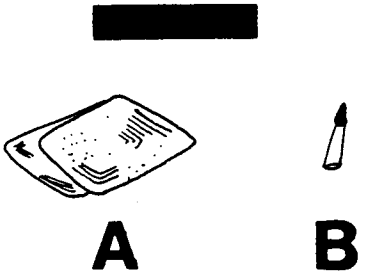

Figure 18. Lepisosteidae indet. A, scale; B, tooth. Scale in centimeters.

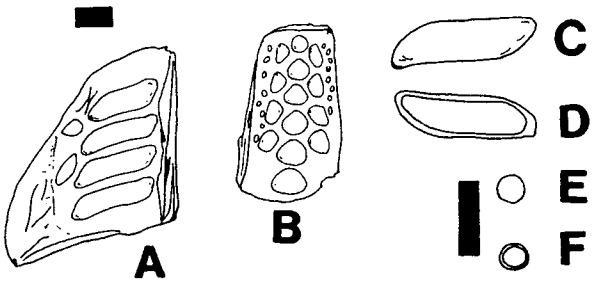

Figure 19. *Anomoeodus phaseolus*. **A**, left splenial section, occlusal view; **B**, vomerine, occlusal view; **C**, median splenial crusher tooth, occlusal view; **D**, medial splenial crusher tooth, basal view; **E**, vomerine or lateral crusher tooth, occlusal view; **F**, vomerine or lateral crusher tooth, basal view. Scale in centimeters.

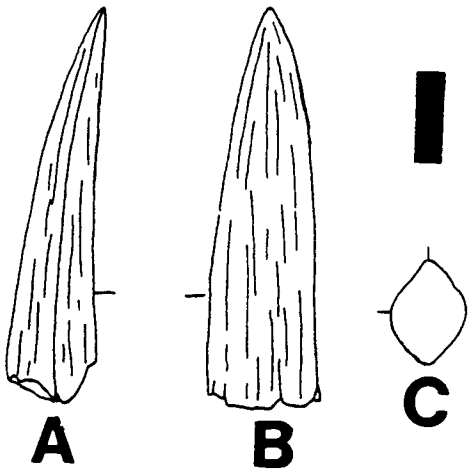

Figure 20. Tooth of *Xiphactinus audax*. **A**, profile view; **B**, labial view; C, cross-section at points marked on A and B. Scale in centimeters.

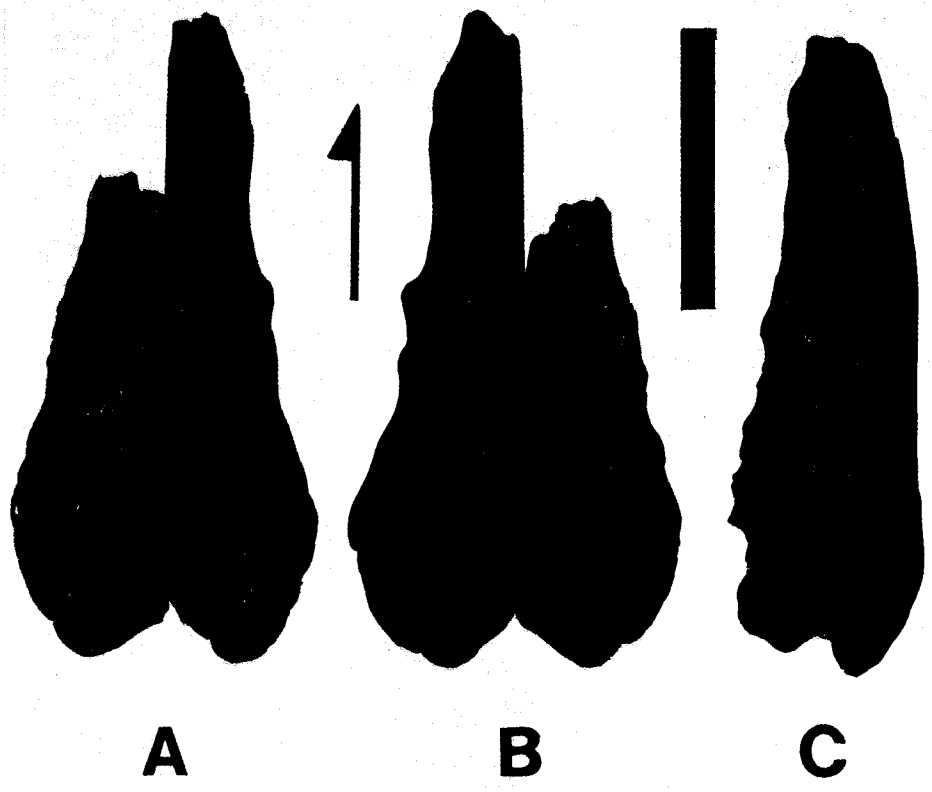

Figure 21. Anterior dentary fragment of *Saurodon* sp. (USNM 392103). **A**, ventral view; **B**, dorsal view; **C**, mesial view of right-hand side. Arrow indicates posterior direction. Scale is 5 centimeters.

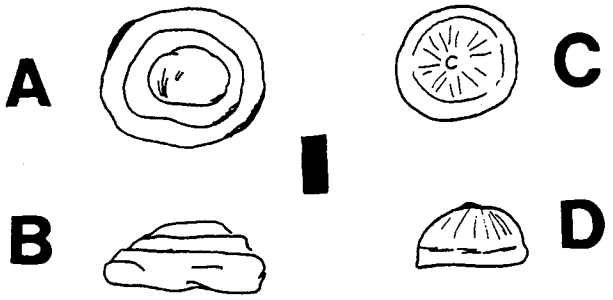

Figure 22. A-B, crusher tooth of *Albula* sp.: A, occlusal view, B, lateral view. C-D, crusher tooth of *Paralbula casei:* C, occlusal view; D, lateral view. Scale in millimeters.

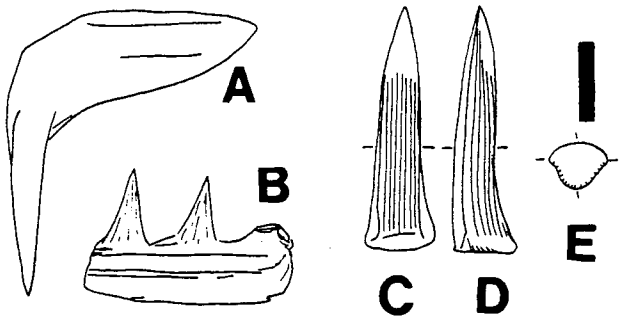

Figure 23. *Enchodus* cf. *E. petrosus*. A, palatine fang attached to palatine bone; B, lateral jaw section; C, palatine fang, posterior view; D, palatine fan, lateral view; E, palatine fang cross-section at points marked on C and D. Scale in centimeters.

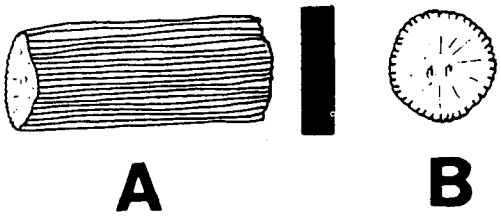

Figure 24. ?Spine of *Cylindracanthus ornatus*. A, lateral view; B, cross-section. Scale in centimeters.

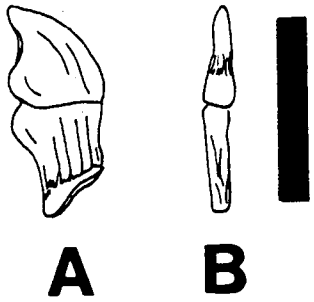

Figure 25. Pharyngeal tooth of *Stephanodus* sp. A, lateral view; B, posterior

Figure 26. Bony-fish coprolite. Scale in centimeters.